The Miniaturized Mössbauer Spectrometer MIMOS II for the Asteroid Redirect Mission (ARM): Quantitative Iron Mineralogy and Oxidation States

Christian Schröder[1], Göstar Klingelhöfer[2], Richard V. Morris[3], Albert S. Yen[4], Franz Renz[2] & Trevor G. Graff[5]

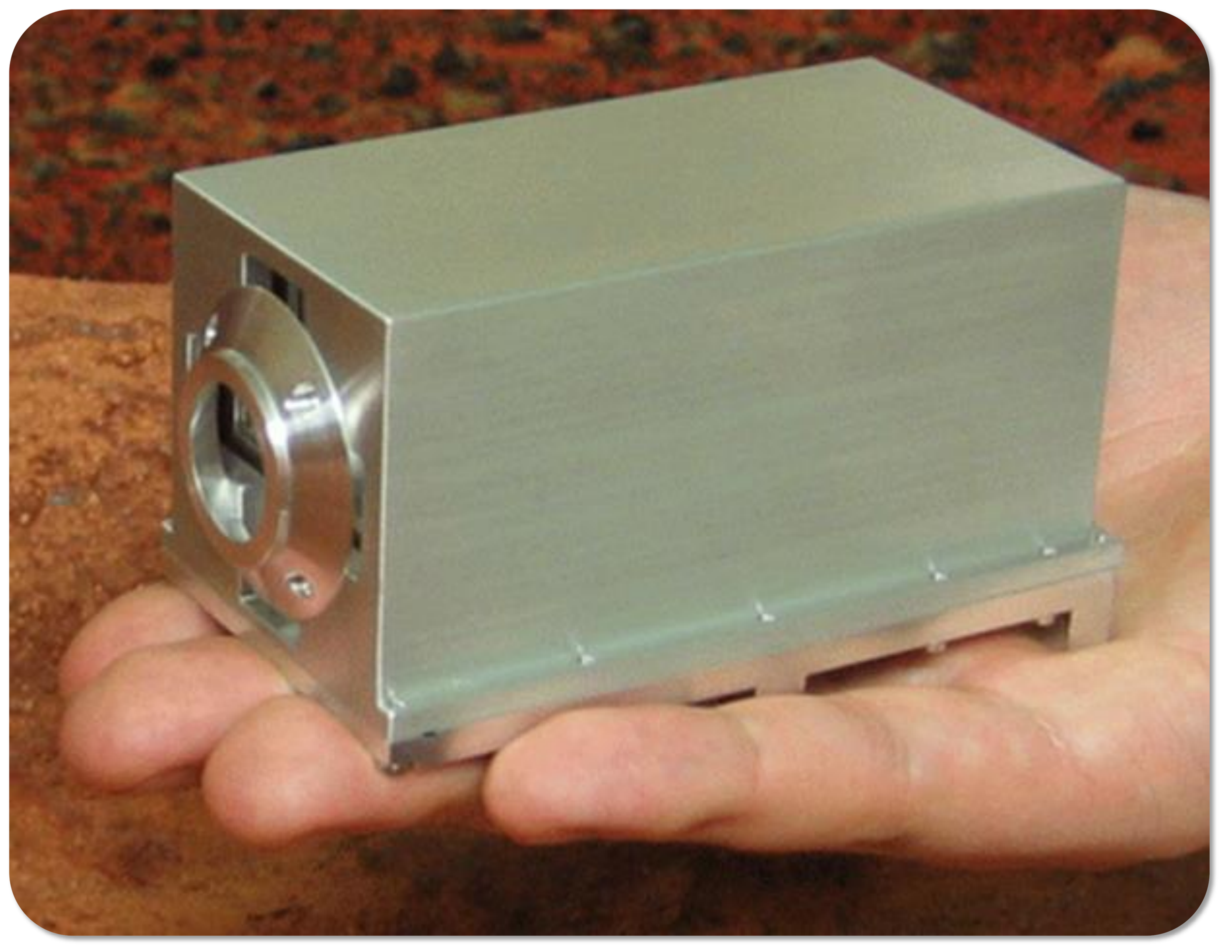
[1]University of Stirling, UK, christian.Schroeder@stir.ac.uk; [2]Leibniz Universität Hannover, Germany; [3]NASA-JSC, Houston, TX; [4]JPL-Caltech, Pasadena, CA, [5]Jacobs at NASA-JSC, Huston, TX

INTRODUCTION

The miniaturized Mössbauer spectrometer MIMOS II [1] is an off-the-shelf instrument, which has been successfully deployed during NASA's Mars Exploration Rover (MER) mission [2-4] and was on-board the ESA/UK Beagle 2 Mars lander [5] and the Russian Phobos-Grunt sample return mission [6]. We propose to use a fully-qualified flight-spare MIMOS II instrument available from these missions for in situ asteroid characterization with the Asteroid Redirect Robotic Mission (ARRM).

INSTRUMENT DESCRIPTION

MIMOS II consists of a sensor head and an electronics board. The sensor head can be mounted on a robotic arm and needs to be brought in contact with the sample to be analyzed. No sample preparation is necessary. The sensor head carries the radiation source (Co-57, halflife 270 days) and detector system, and has a volume of 50 × 50 × 90 mm³. The electronics board holds data acquisition and instrument control units (CPU + FPGA), voltage converters, and electrical and data interfaces to the spacecraft. It measures 100 × 160 × 25 mm³. The whole system weighs <500 g, power consumption is 4 W during data acquisition, and data product size per analysis is 512 kBytes (4 Mbit).



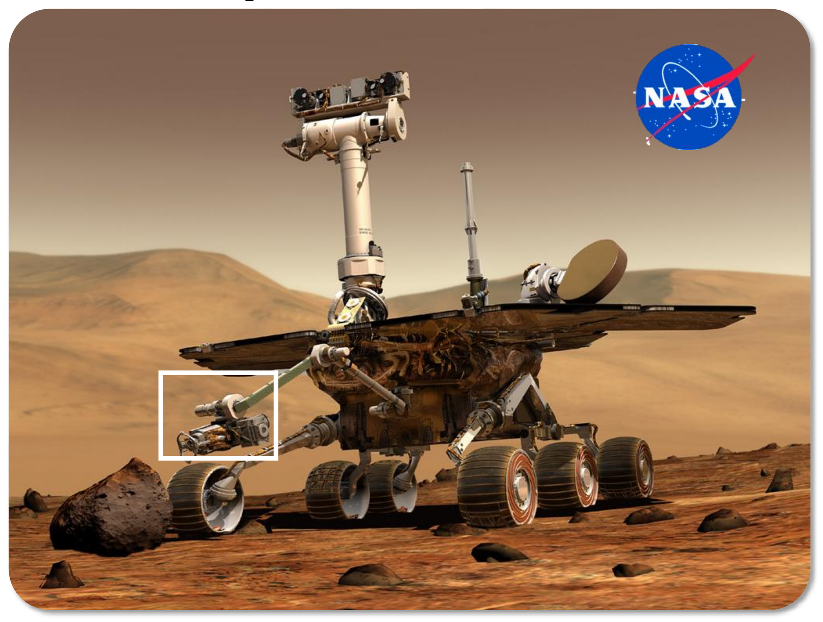
AIMS

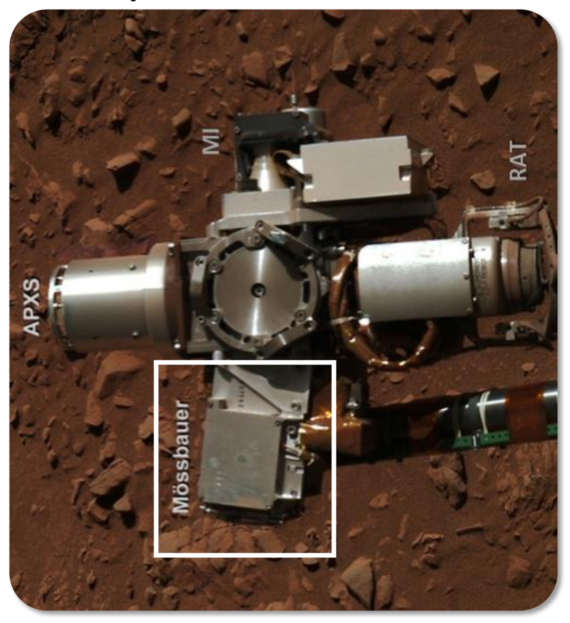
Mössbauer spectroscopy provides quantitative iron mineralogy (e.g. silicates, oxides, and sulfides), iron oxidation states, and insights into magnetic properties. This information is vital for ARM and NASA goals:

- **Science**
  - ✓ Link asteroid to known meteorite group
  - ✓ Thermal and shock history
  - ✓ Volatile/water content
  - ✓ Space weathering
- **Planetary Defense**
  - ✓ Geotechnical properties
  - ✓ Thermal properties
  - ✓ Electromagnetic properties
- **Asteroidal Resources and ISRU**
  - ✓ Radiation protective properties
  - ✓ Water
  - ✓ Oxygen

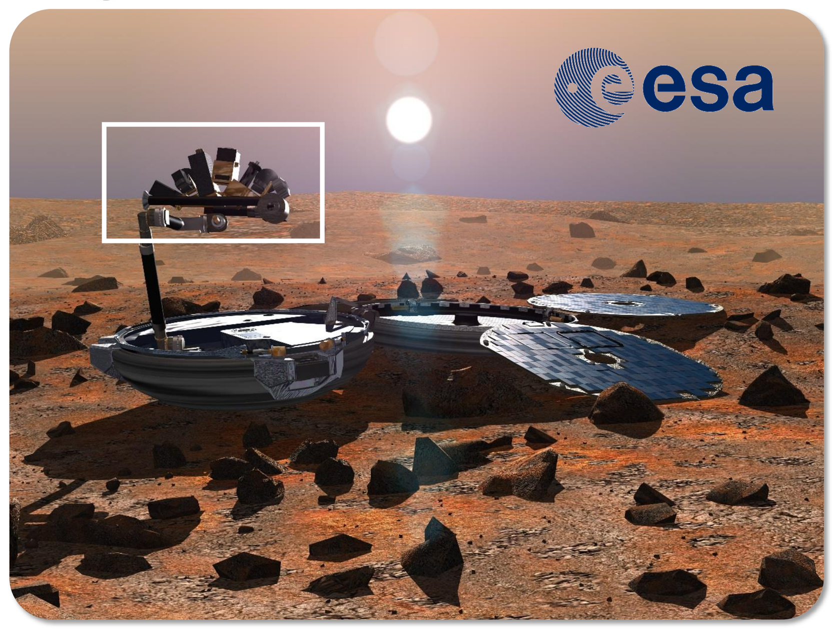
INSTRUMENT FLIGHT HERITAGE

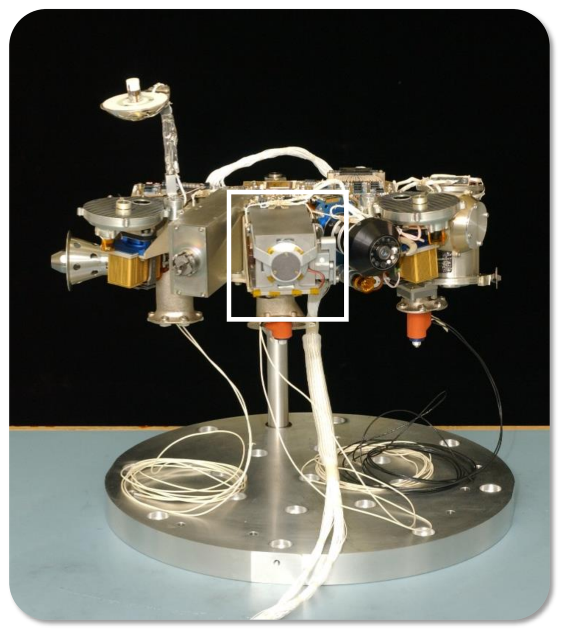
Mars Exploration Rovers (NASA)



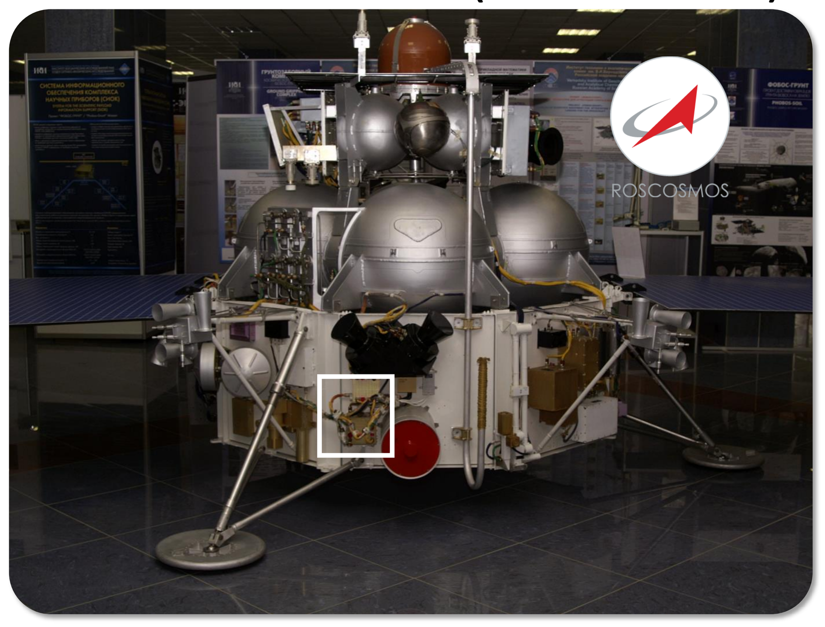


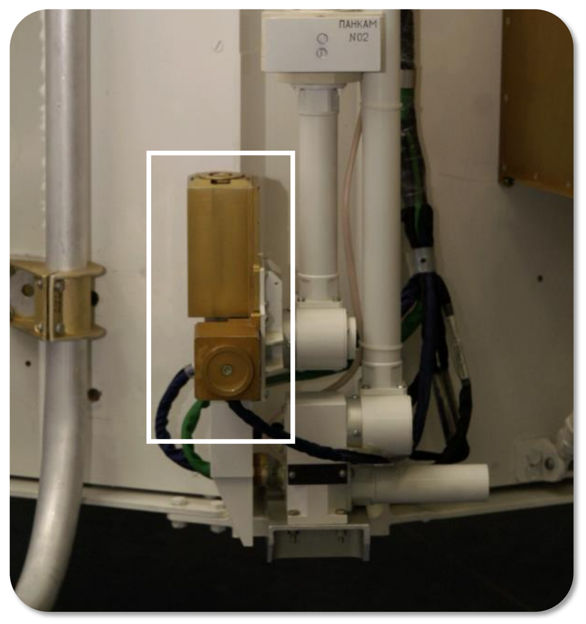
Beagle 2 (ESA)





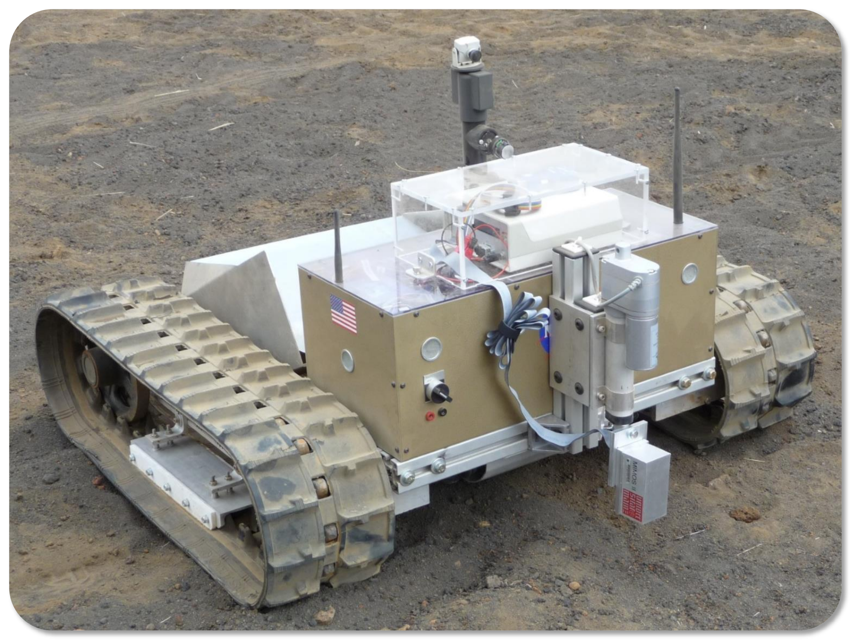
Phobos-Grunt (Roscosmos)

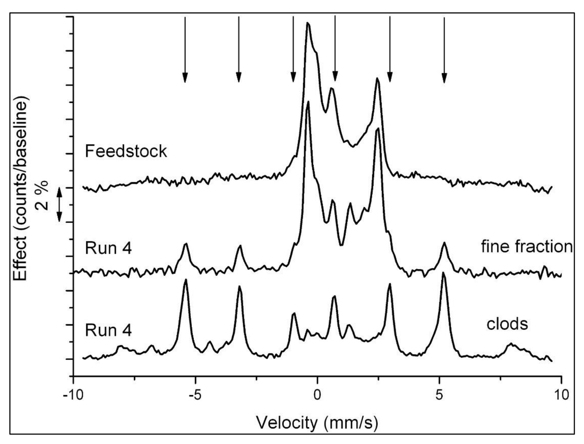




ISRU

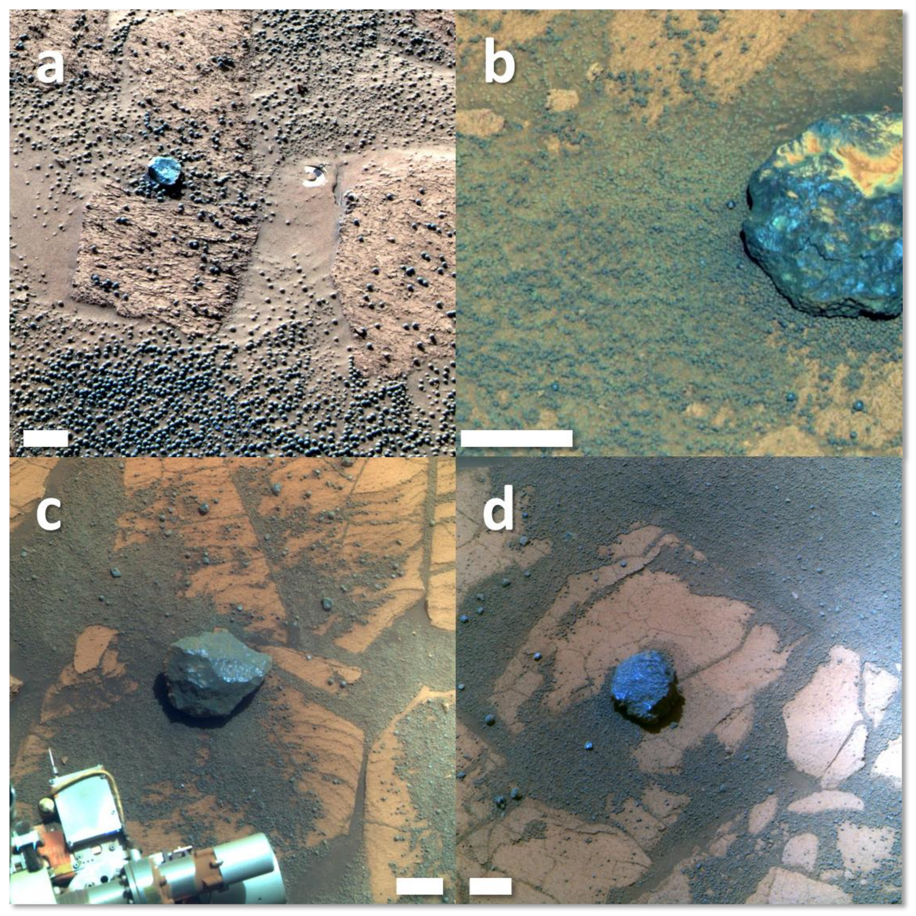
In ISRU experiments to extract oxygen from lunar regolith, we used Mössbauer spectroscopy as both a prospecting tool and a process monitor [12-16]. Feedstock is selected for high FeO content, the predominant mineralogy determines the processing temperature (ilmenite: 900°C; olivine: 1000°C; other FeO-bearing phases: 1100°C). The amount of metallic iron formed in the process is proportional to the amount of oxygen released.



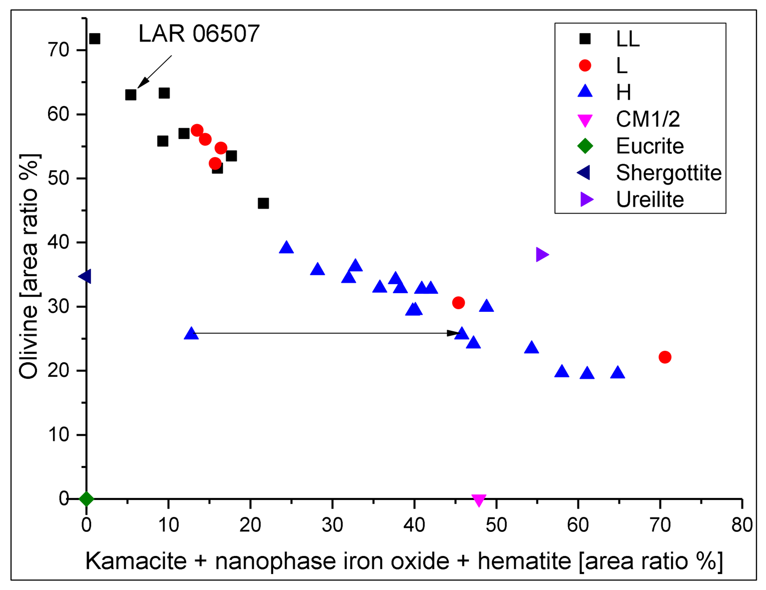


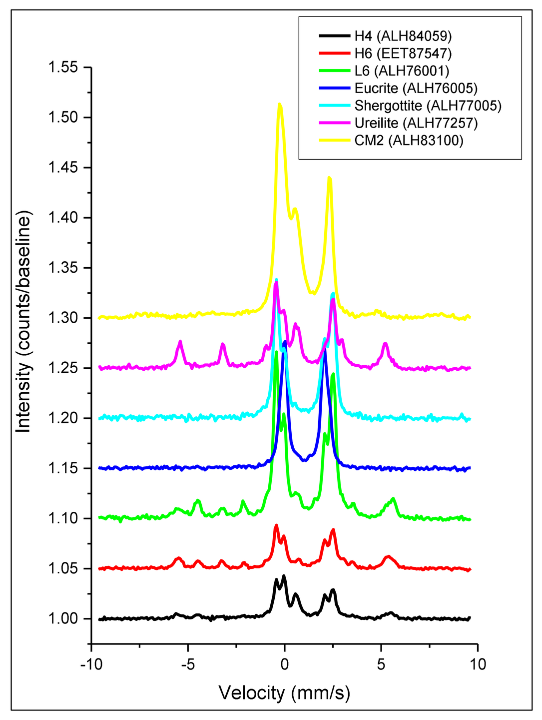
METEORITE IDENTIFICATION & GROUPING

Meteorites on Mars: We used a combination of Mössbauer and geochemical data to identify stony meteorites on Mars, show that they are probably paired, and that they are akin to the silicate fraction of mesosiderites [7,8]. We used the ferric iron content of these meteorites to derive a chemical weathering rate form Mars [9].



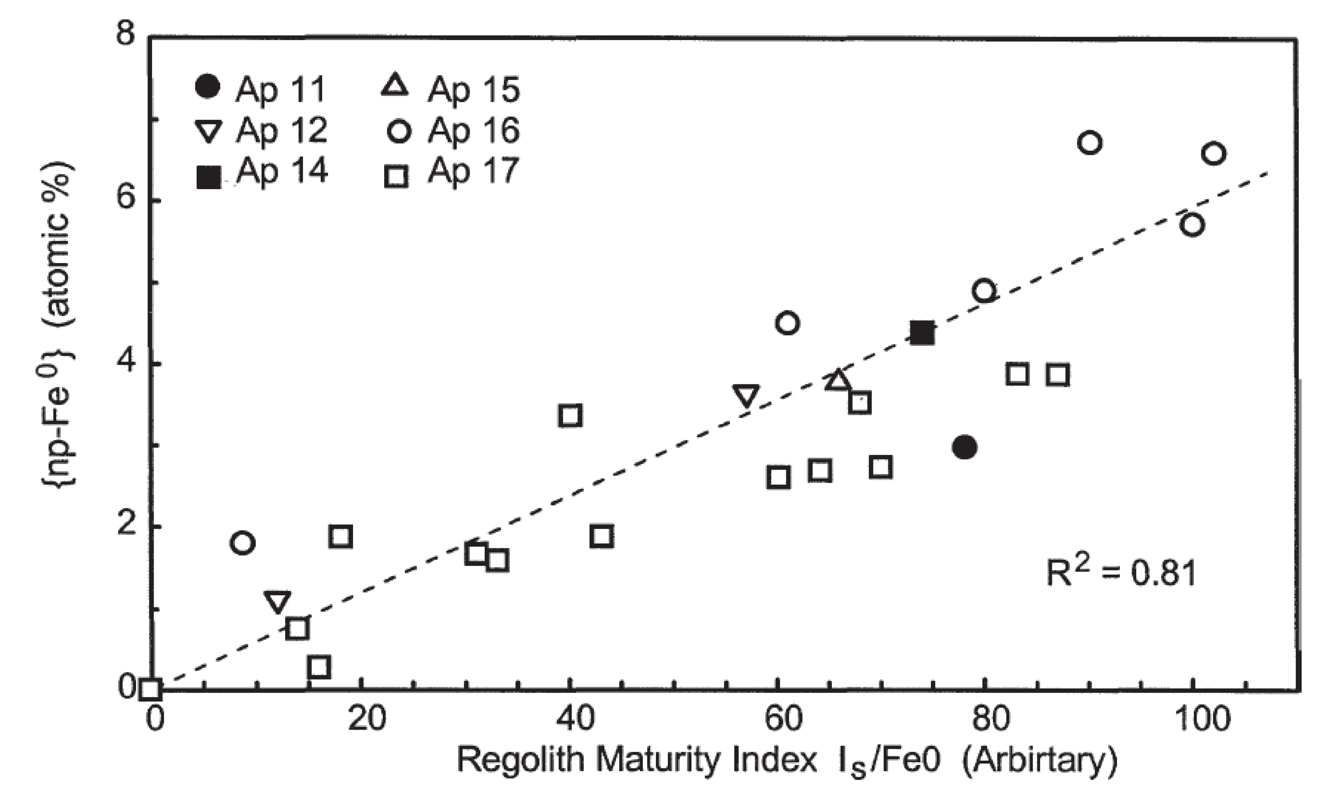
Meteorite grouping: We demonstrated non-destructive classification of meteorites using a combination of Mössbauer and magnetic susceptibility measurements [10].





SPACE WEATHERING

The amount of metallic iron in lunar regolith increases with surface residence time as a micrometeorite impacts [11].



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